8 Research Needs Associated with CAFOs

8.1 Overview

Identified research needs related to CAFO issues fall into several categories. The categories are interactive and mutually supporting. One category is stressor evaluation and quantification. A second category is method development; new methods are needed to rapidly and inexpensively measure stressor levels. New methods are also needed to identify sources of stressors in the environment. A third research category encompasses process research. Process research will involve several levels of work from bench-scale to field-scale. How may waste treatment systems be optimized for control of different stressors? How may they be made cost effective? Can salable products be generated from waste streams? Different stressors will have to be addressed individually and in combination. The fourth category of research needs relates to stressors in the environment. Fate and effects of specific stressors must be elucidated. Management practice effects on stressors must be studied. Transport of stressors in different media from sources to receptors must be understood. Other topics of research that are presented in more detail are ground water research, aerosol research, and land reclamation.

8.2 Stressor Evaluation and Quantification

The first two research categories are closely related. Stressor evaluation and quantification is a fundamental need in identifying problem areas. Current methods are quite good for measuring nutrient levels in various media. Methods for sediments in water are also good. Source identification for nutrients is more of a problem. In some cases, isotope analysis of C, N, and P could lead to identification of sources of stressors. Much work needs to be done to make isotope methods more readily applicable. Quantitative analysis of antibiotics, EDCs, and pathogenic microorganisms in waters, soils, sediments, and manures is needed to evaluate stressor content and movement. Rapid, precise methods need to be developed for analysis of these stressors in the different matrices. Methods for analysis of EDCs and antibiotics in different matrices will ultimately rely on GC-MS and HPLC-MS for quantification. Analysis of pathogenic organisms will require a completely new approach. Currently, fecal coliforms (FC) and fecal streptococci (FS) are used as indicators of fecal pollution. There may easily be cases where pathogenic organisms may exist with no associated FC or FS. The best approach requires developing methods that may be applied to water, soil, sediment, or manure to directly detect and quantify specific pathogens.

The organisms most commonly implicated in human illness should be included in the test method. Among the organisms of concern are *E. coli* O157:H7, *Salmonella* spp., *Campylobacter jejuni*, *Listeria monocytogenes*, *Leptospirillum* spp., *Cryptosporidium parvum*, and *Giardia lamblia*. These bacterial pathogens are perhaps the most readily detected and most commonly implicated in causing health problems. With the advent of genetic analysis methods, it is possible to develop means to specifically identify organisms and track them to their source. Work has been done on source identification with some organisms in agricultural areas of Oregon and California. Protozoan parasite detection and enumeration is much more difficult. Currently, the methods require large sample volumes, are laborious, and require highly skilled analysts. Development of rapid methods for identification and enumeration of protozoan parasites is highly desirable.

Associated with the need for microbiological methods is the need to determine the survival of known pathogens under different conditions. Treatment or storage of manures should have effects on microbial populations. These effects should be determined to establish the utility of different treatment systems for reducing pathogen loads. Detection and enumeration methods for the different organisms are required to address this need. Compilation of a database of microbiological information is needed to assess and track epidemiological information related to pathogens in animal waste. Little of this information is readily available. Similarly, the database should include animal disease epidemiological data as well. Existing literature on baseline mortality of animals needs to be compiled as well. The potential financial loss from an outbreak of animal pathogens is on the order of several billion dollars.

8.3 Process Research

The third major category of research needed to address the environmental challenges of CAFOs is process research. Process research entails examination of waste handling in the different sectors of agriculture. Different treatment processes are effective in controlling different stressors. Waste treatment processes with potential application to animal waste include lagoon storage and lagoon modification, aerobic digestion, anaerobic digestion, staged aerobic/anaerobic digestion, thermophilic digestion, composting, and lime treatment. Much work is needed to optimize these systems for controlling the different stressors. Conditions of treatment that control nutrients may have little effect on pathogen survival or may even encourage regrowth.

Stabilization of nutrients by alum is a new area of research. The use of alum on poultry litter has shown greater promise in stabilizing P to prevent its runoff to surface waters and leaching to ground waters. Alum also stabilizes ammonia, making poultry litter more valuable as a fertilizer. Conditions that control pathogenic organisms may have little effect on nutrients. The different systems must be optimized for waste type, stressor reduction and cost.

Another aspect for cost control is configuring treatment systems to generate salable products. Anaerobic systems offer the possibility of CH_4 production. Some processes may recover fertilizer elements in condensed forms that are more readily salable. Methane may potentially provide energy for operation on the farm. As a lower cost alternative, composting is a useful treatment alternative. Establishing performance characteristics for different animal wastes and effects on different stressors is an important goal. Performance of poorly practiced composting must be established with regard to stressor control. While the major effort will focus on systems for larger CAFOs, the smaller producer should have alternatives for waste handling available. Smaller systems should be developed to address the same problems for the smaller producer. A complete systems approach will be needed to optimize nutrient control, pathogen control, and value recovery.

8.4 Fate and Effects of Stressors in the Environment

The fate and effects of stressors in the environment and the transport of those stressors in the environment generate questions that are difficult to answer. Land application is a major practice for the disposal of animal wastes from large and small facilities. The effectiveness of buffer strips with different types of vegetation, width, and interaction with other soil management procedures should be evaluated. Related to land application is the control of sediment generation from application sites and CAFO facilities themselves. Study of engineered structures to collect sediments and management techniques is needed with regard to other stressors that may move with sediments. Sediments offer attachment sites for nutrients, EDCs, and pathogens. How effective is reducing sediment movement in reducing other stressor movement into waterways?

Another water management tool proposed to be useful in waste management is the constructed wetland. How do constructed wetlands perform over long term use under different climatic conditions?

Are they efficient in solid/liquid separation? What functions do different aquatic plants carry out? How are they best monitored for performance? Do they function to remove excess phosphorus? What air emissions may be expected from different types of wetlands?

8.5 Ground Water

Future research related to CAFO impact on ground water may be categorized into the following broad areas: 1) transport and fate; 2) hydrogeology; 3) testing and monitoring; 4) risk management; 5) prevention; 6) predictive modeling; and 7) impact of CAFOs on ground water resources. Improved knowledge of the major factors affecting nutrient transformation, transport, and reactions in ground water is an area that requires attention by soil/environmental scientists, hydrologists, hydrogeologists, and environmental engineers. Research is needed to understand the fate of nitrogen under aerobic and anaerobic conditions (nitrate, ammonium, organic-nitrogen) in stream riparian buffers, wetlands, and hyporheic zones (i.e., groundwater-surface water interface). Transport of nitrate by preferential flow from treated soil/storage ponds to ground water and/or tile drains is a critical area of research. Research documenting phosphorus losses from soil receiving manure via subsurface tile drainage is limited. Leaching of solutes below earthen waste ponds/lagoons to deep ground water, where the primary mode of transport to ground water is unsaturated flow, warrants further research. The mechanism of self-sealing, particularly the effect of wetting/drying cycles on reducing the extent of sealing in lagoons is an area that needs further research. A method needs to be developed to account for sealing effects and related factors, such as temperature, waste characteristics, soil structure and texture, pond depth, and frequency of pump down.

The survivability and transport of manure pathogens in soil and aquifers is not well characterized, especially transport mechanisms for *Cryptosporidium* oocysts in the subsurface. More studies and information are needed on their movement in soils. Studies are needed to investigate the impact of periodic freezing-thawing -- a common phenomenon during United Kingdom winters particularly in upland sheep-farming areas (ref?). Little research has focused on the role of plant roots and micro- and mesofauna in the translocation of pathogens. The importance of preferential transport of microorganisms by macropores from treated soils and/or leachate from earthen storage ponds warrants future research. Further investigation is needed into the effectiveness of riparian buffers and wetlands for removal of pathogens from subsurface water. Improved fundamental understanding of sorption/desorption characteristics and die-off rates of microorganisms in different soils and aquifer sediments is essential in designing for and evaluating the efficacy of alternative mitigating measures.

Continued research on fundamental understanding of movement of ground water (hydrogeology) in unsaturated soil (vadose zone hydrology) is a major prerequisite for studying source and prevention issues. Research is warranted to investigate seepage losses from storage pond side slopes subject to frequent water level fluctuations. Technology is needed for measuring infiltration for low permeability soils. Further research is warranted to compare evaporation from clear water and animal wastewater, which may affect water balance in ponds and thus seepage losses.

Standardized methods are needed that may relate P quantity and intensity factors to desorption and downward movement of P and thus to the potential for P loss in subsurface runoff; i.e., soil tests for predicting potential for P loss in leaching and drainage waters. Soil monitoring methods to accurately track nutrient leaching in soil to ground water warrants further research.

Operational research (e.g., systems analysis and optimization) and modeling are important research areas, especially for risk management at the watershed scale. Because of uncertainty in seepage rates and other environmental factors, effort should be directed toward the development of stochastic, risk-based approaches for the design and performance evaluation of detention ponds/lagoons. Developing a reliable, risk-based regulatory system that would be acceptable to regulators, operators, and the general public is a future research need. Developing predictive models based on sound scientific principles for assessing the impact of CAFOs on ground water and for risk-management in watersheds is an area of future research.

Preventing pollutants derived from animal waste from reaching ground water may result in substantially reduced costs, otherwise incurred with treatment or removal of pollutants in drinking water. This would require developing appropriate management practices for animal waste to reduce potential groundwater pollution, e.g., by nitrate and pathogens. Methods need to be developed to evaluate the impact of animal waste management practices at the individual, local level and at the integrated, watershed level.

Models are useful tools to identify sources and to estimate the relative loading of pollutants from various management scenarios. Their role is best realized in complementing and not replacing environmental monitoring. Rather than relying on costly intensive monitoring, simulation models may aid in the development of cost-effective and optimal monitoring network. More effort is needed for modeling pathogen transport and fate in the soil and groundwater. Models need to be revised to account for the complex interactions governing movement of microorganisms and other pollutants in soils as well as in micropores. Incorporating a macropore flow component may improve the performance of models to predict the fate of injected animal manure. Because of uncertainty in seepage rates and factors governing movement of pollutants (e.g., pathogens, nutrients, and salts), probabilistic/stochastic-based modeling approaches will be needed for risk-based planning and decision making.

Evaluating the performance of alternative abatement measures will benefit from improving the capability of current watershed models to simulate the capacity of riparian buffers, vegetative filtering strips, detention reservoirs, natural/constructed wetlands, and tillage practices to reduce the impact of manure from agriculture and runoff from storage facilities on water quality. Developing modeling systems that integrate processes across watersheds (both surface and groundwater) warrants further research. Integrating modeling technology with systems analysis will be needed for optimal selection of alternative abatement strategies.

Future research may be needed to address the following institutional questions: At what level is risk management conducted (individual home, farm, or community)? What strategies are used to control groundwater contamination? How do we make decisions on whether to do community treatment versus point-of-use treatment versus development of new water resources? Research is required to emphasize the need to forge a working relationship among scientists, regulatory agencies, and stakeholders to develop BMPs that are both environmentally sound and feasible in the short and long terms. Research is warranted on the impact of socio-economic and political constraints on environmentally effective decision-making.

8.6 Aerosol Research

Aerosol issues form another field of work in the handling of CAFO waste. Often, the first environmental impact of a CAFO is the odor generated by the animal waste. With the concentration of large numbers of animals in smaller areas the potential for odor generation is high. The public may perceive problems in such areas if the odors generated are irritating. Production of particulates from CAFOs is a concern because the particulates may easily fall into the regulated size classes of PM2.5 or PM10. PM2.5 particles are respirable deep into the lung and may be a source of irritation or infection. Do particulates carry intact microbial cells, endotoxins, and allergens? Can they be detected? Are there species-specific aerosol patterns related to housing types and waste system types? Can housing systems be designed to minimize particle generation? Odor impacts are largely subjective and difficult to measure objectively. Can a classification system be created to make objective measures of odor problems? The system must be able to identify and quantify odors with regard to duration, intensity, frequency and offensiveness. Are there good emission rate models for ammonia, H_2S, VOCs, and particulates? Are there ways to reduce emissions?

Ammonia falls into more than one group of problems because it has a strong odor, is a nutrient, and may attach to particles. Volatile organic compounds also contribute to odor problems. Many of these compounds are contained in manure and are created by microbial action during storage or digestion of the manure. Can the processes used for waste handling be modified to reduce odor generating organic compounds? Staged treatment processes may be able to reduce odor compounds concurrent with treating the waste for other stressors. Would a biofilter be able to reduce odor compounds sufficiently to reduce the impact of odors?

8.7 Land Reclamation

Reclamation of disturbed land is another possible use for animal waste. Many areas of the United States have large tracts of land seriously disturbed by many causes. Strip-mined land, mine spoil banks, seriously burned-over land, and new highway construction may create highly disturbed land. Much of the soil replaced or exposed in these areas has little protection from further degradation from erosion and supports poor plant growth. A potential use of animal manure is to create new soils by mixing manures with excavated dredge spoil from waterways and application of the material to unproductive land. The manure contributes organic matter and nutrients to the soil. Manure also conditions the soil to be more friable and hold more water for plant growth. The amount of available land in different classes and the quantity of manufactured soil that could be applied at one time must be determined. Another use for manufactured soil is restoration of heavily eroded soil in the United States. Return of soil material to areas that have experienced losses of topsoil could be a beneficial use of manure composted together with freshwater dredge material from the large river systems in the United States. The U. S. Army Corps of Engineers moves about 100 million tons of dredge material every year. Some of this material could be composted together with manure to make a product that could replace eroded soils.